Fermilab

July 20, 1983

TO: Anthony Malensek

FROM: Thornton Murphy CJM

SUBJECT: Actual Density of the Neutrino Berm

I mentioned that we had found a wet density of 2.24 gm/cm^{-3} (140 lbs/ft^3) in the accelerator berm, and that Don Cossairt and I got better agreement between real beam-on neutron rates and CASIM when we used this value instead of 2.0 gm/cm^{-3} (125 lbs/ft^3). I enclose two graphs of wet density as a function of depth in the Neutrino berm, at two different points along the berm at very different dates. Figure 1 shows the density measured this year just upstream of Lab E (y = 107,740'), and Fig. 2 shows the density measured as the berm was built in 1971 near y = 103,700 (Tom Pawlek's compilation). These graphs confirm that an average in the range of 2.23-2.27 is appropriate. Figure 2 shows that you can quibble about the last significant figure in the above density, dependent on the depth in the berm and whether you are looking at sand or clay. I conclude that a conservative density to use near beam elevation is 2.25±0.02.

I also ought to convince you why one should use "wet" density instead of "dry" density, and fill you in on the history of the confusion. For reasons involving an ASME standard which I do not understand, soil analysis firms always report a dry density, defined as the weight of a sample after baking out all the water in an oven for some prescribed number of hours, divided by the original (wet) volume. Since this is the density which appears on their reports, this is the number which sometimes gets passed along to physicists by Tevatron Construction or its predecessors, Architectural Services and DUSAF. Fortunately, the soil firms also report fractional water content, defined as 1 - (dry weight/wet weight), so one can reconstruct the wet density. The water content is typically 15%.

In order to convince myself that the wet density was more appropriate to use in shielding calculations, I had a conversation with an engineer at the firm who was doing our soil analyses in 1980. He assured me that the wet density is seasonally invariant and independent of recent rainfall, except for the top few feet. The clay and sand remain saturated with water as the water oozes its way to the aquifer or laterally through sand seams to shallow wells.

The last point one might quibble about is whether the average Z and A used in various persons' programs is for wet or dry soil. Water certainly has lower values of A and Z than dry soil. I leave that fine point to you and Andy VanGinneken, since I suspect that it is buried in the noise of the uncertainty of the particle production models and energy loss mechanisms in the programs.

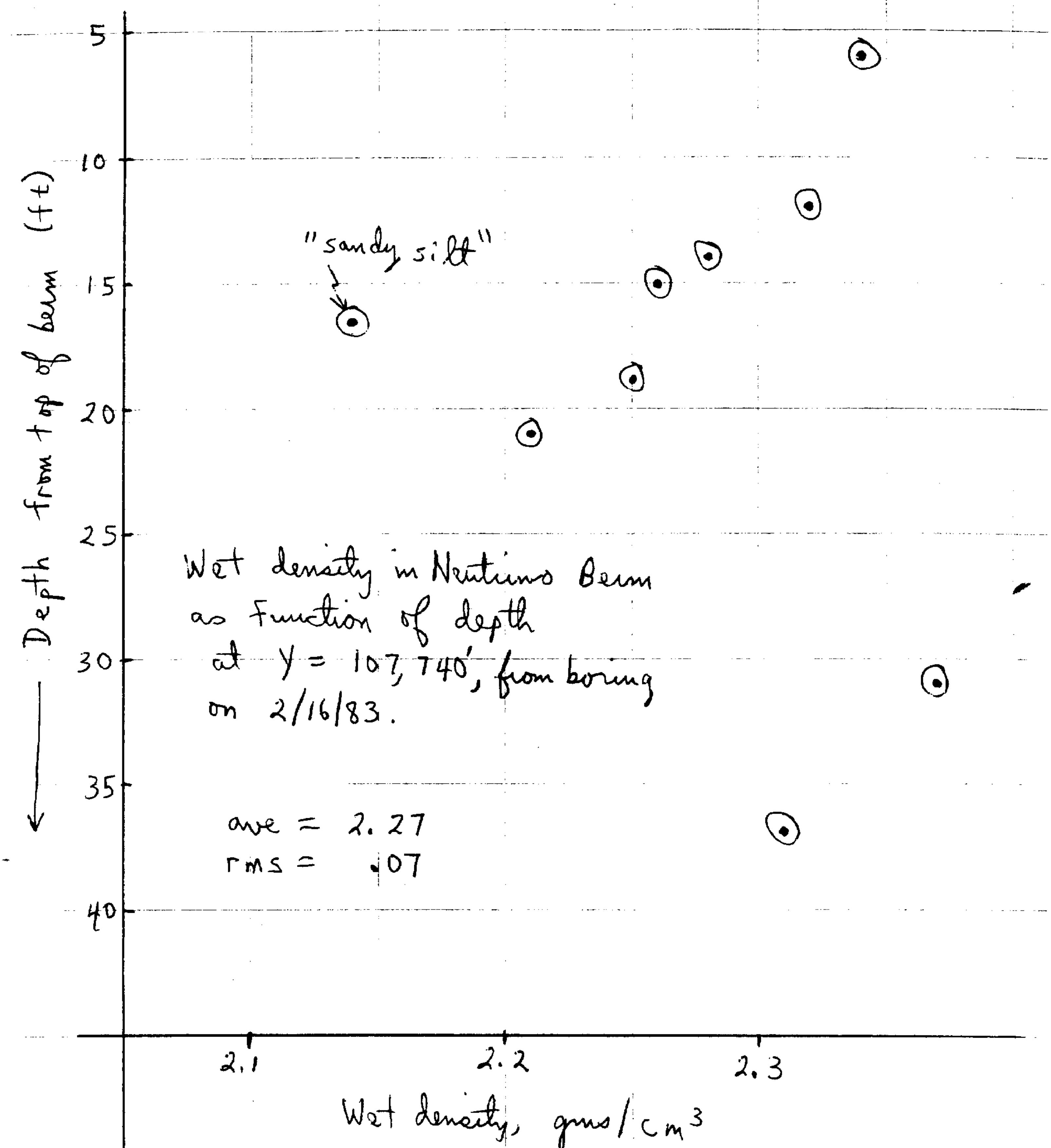
Depth from top of berm (ft)
5
10
15
20
25
30
35
40
"sandy silt"
Wet density in Neutrino Berm
as Function of depth
at y = 107,740', from boring
on 2/16/83.
ave = 2.27
rms = .07
2.1
2.2
2.3
Wet density, gms/cm³

Fig. 1

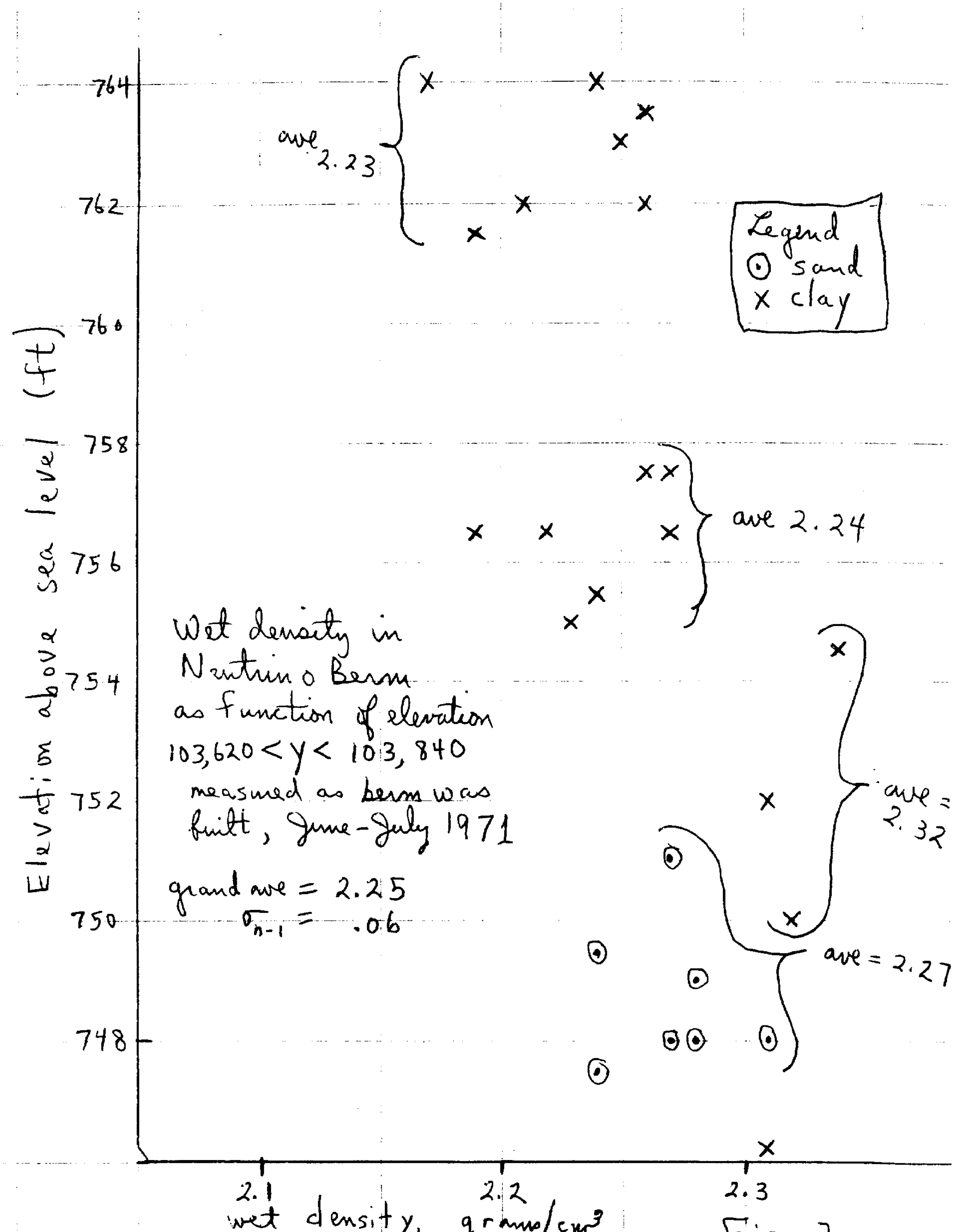
Elevation above sea level (ft)
764
762
760
758
756
754
752
750
748
2.1
2.2
2.3
wet density, grams/cm³
ave 2.23
ave 2.24
ave = 2.32
ave = 2.27
Legend
sand
x clay
Wet density in
Neutrino Berm
as function of elevation
103,620 < y < 103, 840
measured as berm was
built, June-July 1971
grand ave = 2.25
σn-1 = .06

Fig. 2